The Metabolizable Energy of Feed Ingredients for Chickens

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Accurate and universally applicable energy values for poultry feed ingredients are necessary to formulate economical rations and especially in the programming of least-cost formulas. In this work, productive energy and metabolizable energy appear as terms in current average analysis tables. These and other terms used to describe the energy value of feeds are reviewed here.

Digestible Energy is the amount of gross energy remaining after deducting the energy that appears in the feces.

Metabolizable Energy is digestible energy minus the energy represented by the urine and combustible gases. Metabolizable energy is the amount of energy available to maintain an animal, perform work, or produce animal products.

Net Energy is the metabolizable energy minus the heat increments (energy of utilization). Net energy represents the amount of energy used for maintenance plus that which appears as work performed, production of flesh and fat, or milk and eggs, etc.

Productive Energy represents net energy defined as the amount of energy stored up as fat or protein in a *growing* or *fattening* animal plus energy used for maintenance.

By definition then, productive energy values for poultry apply only to broilers or replacement stock and do not represent a true net energy value for egg production. Some current tables of energy values of feedstuffs list both productive energy and metabolizable energy values; others list either one or the other. This has tended to confuse the lay public because they often do not know which energy value to use. Ideally, net energy values would be preferable. However, since the net energy value of a given feed varies according to its use, it is difficult to list true net energy values for all the energy functions of a feed. On the other hand, metabolizable energy values of feedstuffs are reasonably constant over a variety of conditions.

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Studies at Cornell University (Hill and Anderson, 1958) and at the University of Connecticut (Potter, 1958) have shown that the metabolizable energy of a diet is more precisely measured than productive energy. This has been confirmed by English workers (Hopkins, 1962). Although there are factors that influence the determination of metabolizable energy values (Sibbald *et al.* 1960, 1961, 1961a), it is only argued here that under reasonably standardized dietary conditions metabolizable energy values are:

1. Reproducible in different laboratories.
2. Little affected by nutritional balance.
3. Highly correlated with performance (feed gain ratios, energy laid down, and growth).
4. Not markedly influenced by genetic differences (breed and strain).
5. Relatively easy to determine.

While productive energy values are:

1. Not readily reproducible.
2. Influenced by nutritional balance.
3. Influenced by density alteration (pelleting).
4. Very markedly influenced by genetic differences (meat production strains vs. egg production strains).

Because of these facts, the authors prefer the use of metabolizable energy values.

This bulletin reports the results obtained on 134 individual samples, representing 44 poultry feed ingredients. They have been evaluated in a total of 29 experiments conducted during the past 4 years, and extend the data of Potter *et al.* (1960, 1961).

PROCEDURE

Experimental diets were formulated by adding, on a dry matter basis, the test ingredient at the expense of a portion of the total diet, or at the expense of a given quantity of cerelose in the basal diet. The rate of substitution was usually between 20 and 66-2/3%, depending upon the ingredient under test. Each diet was fed to 2 to 6 groups of 9 chicks for an experimental period from 2 to 4 weeks of age. Chromic oxide, a totally indigestible and unabsorbable material, was incorporated into the diets at the 0.3 % level for the purpose of relating the quantity of excreta derived from a unit of diet consumed. Excreta collections were made for a 3-to-7-day period after the chicks had been on the experimental diets for a week.

Both the diet and dried excreta samples were quantitatively analyzed for gross energy, chromic oxide and nitrogen. In addition, the diets were analyzed for dry matter content. From these results, the metabolizable energy of the diets, on a dry matter basis and corrected for nitrogen retention, were determined by the use of the following formula:

$$
\text{Metabolizable Calories per gram dry diet} = \frac{\text{Gross Calories/gm. diet} - \left[\frac{\left(\frac{\text{Calories/}}{\text{gm. excreta}}\right)\left(\frac{\text{mg. Cr}_2\text{O}_3/}{\text{gm. diet}}\right)}{(\text{mg. Cr}_2\text{O}_3/\text{gm. excreta})} + 8.22 \frac{\text{gm. N gained/gm. diet consumed}}{} \right]}{\text{gm. dry matter/gm. diet}}
$$

The nitrogen gained per gram diet consumed was calculated by the following formula:

$$
\frac{\text{Gm. N gained/gm. diet consumed}}{} = \frac{\text{gm. N/gm. diet}}{} - \frac{(\text{gm. N/gm. excreta})(\text{mg. Cr}_2\text{O}_3/\text{gm. diet})}{\text{mg. Cr}_2\text{O}_3/\text{gm. excreta}}
$$

To determine the metabolizable energy of feed ingredients on a dry matter basis from the diets with the test ingredient introduced at the expense of the basal ration, the following formula was used:

$$
\frac{\text{Metabolizable Calories per gram test ingredient}}{} = \frac{\text{Metabolizable Calories per gram basal diet}}{} + \frac{\frac{\text{Metabolizable Calories per gram test diet}}{} - \frac{\text{Metabolizable Calories per gram basal diet}}{}}{\frac{\text{Grams test ingredient per gram test diet}}{}}
$$

Where the test ingredients were added at the expense of cerelose, the metabolizable energy of the test ingredients was determined under the assumption that cerelose has 3.64 metabolizable Calories per gram of dry matter. The following formula was used to determine the metabolizable energy of the test ingredient on a dry matter basis:

$$
\frac{\text{Metabolizable Calories per gram test ingredients}}{} = \frac{3.64 \text{ Metabolizable Calories per gram cerelose}}{} + \frac{\frac{\text{Metabolizable Calories per gram test diet}}{} - \frac{\text{Metabolizable Calories per gram basal diet}}{}}{\frac{\text{Grams test ingredient per gram test diet}}{}}
$$

RESULTS

The determined metabolizable energy values of the ingredients used in these studies, corrected to nitrogen equilibrium, are presented in Table 1. These determinations were made on a dry matter basis. Values were then calculated to an air-dry basis assuming 10% moisture in all ingredients, except corn oil, sucrose, tallow, and poultry oil, which were assumed to be moisture-free, and dehydrated cane juice, which had 2.25% moisture. The metabolizable energy of cerelose was found to be 3.60 metabolizable Calories per gram dry matter, or 1470 metabolizable Calories per pound when assuming a 10% moisture material. This value agrees well with the one of 3.64 reported by Anderson *et al.* (1958), and used as a standard in the Cornell work.

Table 2 is a compilation of the metabolizable energy values of feed ingredients for chickens embracing all the available data from Connecticut and Cornell. The combined average figure for the metabolizable energy value of feedstuffs is thought to be more representative than either the Connecticut or Cornell values alone, since it embraces values from a greater sample distribution.

DISCUSSION

To test the accuracy of some of these values, Carmean (1963) used the values of Potter *et al.* (1962) for formulating two least-cost formulas to meet the calculated nutrient content of the New England College Conference broiler ration. The metabolizable energy values were then determined for these least-cost formulas. It can be seen from Table 3 that the calculated values, using the Connecticut and Cornell figures, more closely approach the determined values than do those using the figures from Storrs Agricultural Experiment Station bulletin 371.

In the authors' opinion, one of the best supportive tables of productive and metabolizable energy values is Table 18, Titus (1961). The criticism of this table is that very few values are *determined* values, since most of the calculated values were made using percentage multipliers. Thus, there is a very high degree of correlation between productive energy and metabolizable energy values for the ingredients listed; $r = 0.987$ for 83 ingredients, an almost perfect correlation. A comparison with the correlation between Fraps' productive energy values and the *determined* metabolizable energy values in Table 2, where such corresponding values exist $(N = 32)$ is $r = 0.958$, would seem to indicate the validity of Titus' tables as a whole. It should be remembered, however, that one can have a perfect correlation if all y values are x raised by a factor, yet the metabolizable energy values (y)

would be different for each factor used. There are significant differences in the metabolizable energy values assigned to a given ingredient in Titus' tables and in Table 2 of this bulletin. In general, Titus' figures are higher for those ingredients most likely to be used in poultry rations in the northeast.

There is no true mathematical relationship between productive energy values and metabolizable energy values. One can, however, establish a rule of thumb by dividing the sum of all the productive energy values by the sum of all the metabolizable energy values in any given table. This gives a percentage figure that can be applied to the metabolizable energy value of a ration. If productive energy is known and metabolizable energy value is wanted, multiply the productive energy value by the reciprocal of the percentage figure, i.e., $\frac{1}{\%}$

For tables of energy values in general use today the productive energy value of a ration will be approximately $70\% \pm 3$ of the metabolizable energy value.

TABLE 1. — Metabolizable energy of feed ingredients for chickens.

Feed ingredients	Number of samples	Percent of gross energy metabolized	Metabolizable Calories per pound*	
		Average	Range	Average
Alfalfa meal (15% protein)	1	16		290
Alfalfa meal (17-20% protein)	4	24	430-510	470
Barley, ground	2	61	1061-1130	1090
Barley, ground (W. C.)**	1	60		1060
Barley, ground + fungal enzyme (W. C.)**	1	71		1250
Barley, ground (water treated) (W.C.)**	1	72		1290
Bread meal	1	85		1640
Cerelose	2	99		1470
Corn, ground white, degermed, debranned	2	91	1630-1640	1640
Corn, ground yellow	10	83	1450-1600	1530
Corn bran	2	20	330-450	390
Corn fermentation solubles	1	53		980
Corn gluten feed	3	35	610-680	650
Corn gluten meal (41% protein)	2	69	1440-1460	1450
Corn gluten meal (61% protein)	2	68	1560-1600	1580
Corn oil	2	94	3980-4030	4000
Dehydrated cane juice	1	87		1530
Distillers dried grains, corn	1	34		740
Distillers dried grains with solubles, corn	4	50	850-1180	1050
Distillers dried solubles, corn	6	58	950-1400	1220
Fat, hydrogenated vegetable	1	72		2980
Fat, hydrolyzed animal and vegetable	2	74	3150-3300	3230
Fat, vegetable	2	81	3400-3650	3520
High fat corn base (15% animal and vegetable)	1	82		1780
Feather meal (85-88% protein)	5	44	900-1080	1010
Fermentation product, antibiotic	2	22	370-420	400
Fish meal, Mid-Atl. menhaden (58-66% prot.)	10	59	910-1290	1160
Fish meal, Mid-Atl. menhaden (+ 40% sol.)	1	67		1330
Fish meal, gulf coast menhaden (60-61% prot.)	3	57	1040-1180	1130

TABLE 1. — Metabolizable energy of feed ingredients for chickens. (continued)

Feed ingredients	Number of samples	Percent of gross energy metabolized Average	Metabolizable Calories per pound* Range	Metabolizable Calories per pound* Average
Fish meal, gulf coast menhaden (+ 40% sol.)	1	64		1230
Fish meal, red (58-64% protein)	3	66	1320-1360	1340
Fish meal, high fat (18-19% fat)	3	71	1540-1610	1580
Fish meal, Herring (10% fat)	1	63		1420
Fish meal, Tuna	1	48		880
Fish oil	1	90		3320
Fish solubles, condensed	1	49		950
Grease, yellow	1	64		2670
Hominy feed	2	71	1250-1510	1380
Meat and bone scraps	2	54	760-810	780
Milo, ground	1	82		1530
Oats, ground	2	60	1090-1190	1140
Milo gluten feed	1	52		980
Poultry by-product meal (55-62% protein)	4	63	1120-1390	1260
Poultry oil	5	90	3590-3860	3720
Sesame meal	1	43		760
Soybean oil meal (44% protein)	6	54	970-1080	1020
Soybean oil meal (50% protein)	8	56	1030-1140	1090
Starch	2	98	1680-1690	1690
Starfish meal	1	14		70
Sucrose	1	92		1670
Tallow, fancy No. 1 beef	2	74	3170-3210	3190
Tallow, feed grade	2	74	3060-3190	3130
Wheat, ground	1	74		1320
Wheat, flour	1	76		1390
Wheat middlings, standard	3	50	780-1140	960
Whey, dried	1	54		860
Yeast, brewers' dried	2	46	840-920	880
Zeanin (glutelin)	1	53		1050

*All metabolizable energy determinations were made on a dry matter basis. The values were calculated to an air-dry basis assuming 10% moisture in all ingredients, except corn oil, sucrose, tallow, and poultry oil, which were assumed to be moisture-free, and dehydrated cane juice, which had 2.25% moisture.

**All west coast barley data were from the same original sample.

TABLE 2. — The combined metabolizable energy values of feed ingredients for chickens.*

Feed ingredient	Av. Metabolizable Cal. (per pound)** Connecticut	Av. Metabolizable Cal. (per pound)** Cornell	Av. Metabolizable Cal. (per pound)** Combined average
Alfalfa meal (15% protein)	290	—	290
Alfalfa meal (17-20% protein)	470	620	550
Barley, ground	1090	1280	1190
Barley, ground (west coast)***	1060	—	1060
Barley, ground + fungal enzyme (west coast)***	1250	—	1250
Barley, ground (water treated) (west coast)***	1290	—	1290
Barley, pearled	—	1130	1130
Barley, hulls	—	350	350
Bread meal	1640	—	1640
Cerelose	1470	—	1470
Coconut oil meal, expeller	—	675	675
Coconut oil meal, solvent	—	684	684

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TABLE 2. — The combined metabolizable energy values of feed ingredients for chickens. (continued.)*

Feed ingredient	Av. Metabolizable Cal. (per pound)** Connecticut	Av. Metabolizable Cal. (per pound)** Cornell	Av. Metabolizable Cal. (per pound)** Combined average
Corn cobs	—	240	240
Corn, ground white, debranned	1640	—	1640
Corn, No. 2 yellow	—	1560	1560
Corn, ground yellow	1530	—	1530
Corn bran	390	—	390
Corn fermentation solubles	980	—	980
Corn gluten feed	650	—	650
Corn gluten meal (41% protein)	1450	1510	1480
Corn gluten meal (61% protein)	1580	—	1580
Corn millfeed	—	1470	1470
Corn oil	4000	3950	3980
Cottonseed oil meal, solvent	—	828	828
Dehydrated cane juice	1530	—	1530
Distillers dried grains, corn	740	—	740
Distillers dried grains with solubles, corn	1050	—	1050
Distillers dried solubles, corn	1220	1280	1250
Fat, hydrogenated vegetable	2980	—	2980
Fat, hydrolyzed animal and vegetable	3230	3570	3400
Fat, poultry	3720	—	3720
Fat, vegetable	3520	—	3520
High fat corn base (15% animal and vegetable)	1780	—	1780
Feather meal (85-88% protein)	1010	—	1010
Fermentation product, antibiotic	400	—	400
Fish meal, Mid-Atl. menhaden (58-66% protein)	1160	1310	1240
Fish meal, Mid-Atl. menhaden (+ 40% solubles)	1330	—	1330
Fish meal, gulf coast menhaden (60-61% protein)	1130	—	1130
Fish meal, gulf coast menhaden (+ 40% solubles)	1230	—	1230
Fish meal, red (58-64% protein)	1340	—	1340
Fish meal, high fat (60%) (18-19% fat)	1580	—	1580
Fish meal, Herring (10% fat)	1420	—	1420
Fish meal, Tuna	880	—	880
Fish oil	3320	3660	3490
Fish solubles, condensed	950	—	950
Glucose	1490	1490	1490
Grease, yellow	2670	3520	3100
Hominy feed	1380	1350	1370
Ipil-ipil leaf meal	—	370	370
Lard	—	3980	3980
Meat scrap (50-55%)	—	870	870
Meat and bone scraps (44%)	780	—	780
Milo, ground	1530	1480	1510
Milo gluten feed	980	—	980
Molasses, blackstrap	—	890	890
Mungo beans	—	1040	1040
Oats, ground	1140	1190	1170
Oats, hulless (Vicar)	—	1540	1540
Oats, hulls	—	150	150
Oats, rolled	—	1450	1450
Peanut meal	—	1200	1200
Poultry bi-product meal (55-62% protein)	1260	—	1260
Poultry oil	3720	—	3720
Rice bran, coarse	—	670	670
Rice bran, fine (rice polishings)	—	1310	1310
Rye (tetrapetkus)	—	1300	1300
Safflower hulls	—	410	410
Safflower meal, 44% protein, solvent	—	770	770
Safflower meal, 20% protein, expeller	—	770	770

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TABLE 2. — The combined metabolizable energy values of feed ingredients for chickens. (continued)*

Feed ingredient	Av. Metabolizable Cal. (per pound)**		
	Connecticut	Cornell	Combined average
Safflower meal, 20% protein, solvent	—	530	530
Sesame meal	760	870	820
Shrimp, dried whole	—	980	980
Soybean hulls	—	10	10
Soybean oil meal (44% protein)	1020	1020	1020
Soybean oil meal (50% protein)	1090	1150	1120
Soybean millfeed, low protein	—	350	350
Soybean millfeed, high protein	—	570	570
Soybean oil, degummed	—	4210	4210
Soybean soapstock	—	3300	3300
Starch	1690	—	1690
Starfish meal	70	—	70
Sucrose	1670	—	1670
Tallow, fancy No. 1 beef	3190	3230	3210
Tallow, feed grade	3130	—	3130
Tallow, pure beef	—	2860	2860
Wheat, ground	1320	1490	1410
Wheat bran	—	510	510
Wheat flour	1390	—	1390
Wheat flour middlings	—	1200	1200
Wheat, red dog	—	1240	1240
Wheat standard middlings	960	810	890
Whey, dried	890	830	860
Yeast, dried brewers'	880	—	880
Zeanin (glutelin)	1050	—	1050

*The combined average data were computed from values used in recent publications from Cornell University and the University of Connecticut, which are noted in the references with an asterisk. Some unpublished data from the University of Connecticut were also included.

**All data were calculated to an air-dry basis assuming 10% moisture for all ingredients, except corn (15%), molasses (20%), and whey (5%). Glucose, sucrose, fats and oils were assumed to be moisture-free.

***All west coast barley data were from the same original sample.

TABLE 3. — Comparison of metabolizable energy of the N.E.C.C. ration and rations equated to the N.E.C.C. ration on a weight basis and with no restriction on weight calculated from different analyses tables.

	N.E.C.C.	Equal ton	No restriction
	Metabolizable energy Calories/lb. (air dry basis)		
Calculated (Conn. bulletin 371)	1441	1441	1392
Calculated (Data in Table 2, Potter *et al.*, 1961)	1360	1363	1300
Determined	1334	1407	1300

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*Denotes publication containing data used in calculating the combined average figures given in Table 2.